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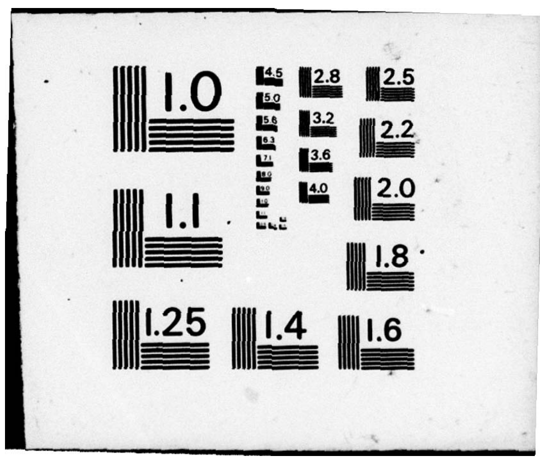
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Draft Translation 566
December 1976

ADA036119

SPATIAL LIMITS OF ECONOMIC COMPETITIVENESS OF HEAT FROM MIXED POWER AND HEAT PLANTS

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HANOVER, NEW HAMPSHIRE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Draft Translation 566	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SPATIAL LIMITS OF ECONOMIC COMPETITIVENESS OF HEAT FROM MIXED POWER AND HEAT PLANTS		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) P. Charroppin		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Cold Regions Research and Engineering Laboratory Hanover, New Hampshire		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE December 1976 13. NUMBER OF PAGES 19
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

HEAT STORAGE
POWER PLANTS
ELECTRICITY

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This document is an inquiry into the spatial competitiveness of calories from mixed plants (producing both power and heat). The investigation deals with electric heating, the use of heat directly from power plants equipped for mixed production and heat from a local community heat source.

DRAFT TRANSLATION 566

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ENGLISH TITLE: SPATIAL LIMITS OF ECONOMIC COMPETITIVENESS OF HEAT FROM MIXED POWER AND HEAT PLANTS,

21 Trans. of mono.

FOREIGN TITLE: LES LIMITES DE LA COMPETITIVITE ECONOMIQUES DE LA CHALEUR PROVENANT DE CENTRALES MIXTES ELECTROGENES-CALOGENES, Paris, 1976 19p.

AUTHOR: P./Charroppin 10

14 CRREL-TL-566

11 Dec 76

12 22p.

SOURCE: Paris, unpublished manuscript, 1976, 19p.

Translated by U.S. Joint Publications Research Service for U.S. Army Cold Regions Research and Engineering Laboratory, 1976, 9p.

ACCESSION for
NTIS White Section
DDC Buff Section
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Dist. AVAIL. and/or SPECIAL
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THE SPATIAL LIMITS OF ECONOMIC COMPETITIVENESS OF HEAT FROM MIXED POWER AND HEAT PLANTS

France mimeo ms 76 19pp

[Article by P. Charroppin, based on the author's Oct-Nov 1975 article entitled "Some thoughts on optimizing long-distance heat transport systems and their storage facilities]

[Text] This document is an inquiry into the spatial competitiveness of calories from mixed plants (producing both power and heat).

The procedure followed here is this: calculate the overall cost, discounted over 20 years, of heating average dwellings using different heating techniques and different kinds of energy suppliers delivering comparable services to the residents. The investigation deals with electric heating, the use of heat directly from power plants equipped for mixed production, and heat from a local community heat source (using heavy N^{O}2 fuel oil).

A. The first step consists in picking out your average dwellings. We selected four kinds of dwellings quite representative of existing or future housing. As is generally done, we assume that the average dwelling has 80 square meters of floor space and 200 cubic meters of interior volume.

1. Types of dwellings

Type I: "Old standards" dwellings

Here we are in fact talking about relatively recent housing, but built prior to the insulation regulations. Hot-water heat (at 90/70^{o}C or 80/60^{o} by radiators or heated by floor and ceiling radiant heat. Natural ventilation.

Type II or "new standards" dwellings

These are housing units built to comply with the recent regulations concerning heat insulation, meaning that they have G coefficients, and 1 to 1.1 watts/cubic meter x °C. Hot-water heat. Controlled mechanical circulation and ventilation. (VNC)

Type III or "reinforced insulation" or "electric" dwellings

These are houses built so as to use electricity most efficiently, with G coefficients between 0.8 and 0.9 watts per cubic meter x°C. Mixed electric heat, floor heated by storage during slack hours in the structures (floors), packup and regulation by convectors. Controlled mechanical ventilation.

Type IV or "advanced technology" dwellings

Here we have a type of housing with a "futuristic" look to it, but we did not think it would be very helpful to include it. Houses of this kind have the same insulation as Type III, but they use new techniques for recovering heat from air exhausts, actually using heat pumps. The technology in this domain is quite advanced. Basically, the heating is done by electricity. But this typs of housing could use heat from other sources, with the proviso that the large mechanical component they contain must, however, necessarily run on electricity. Hence replacement with other energy sources can only be partial. Recovery presupposes that they are equipped with controlled mechanical ventilation.

2. Annual consumption rates of heat

These are more or less the following:

Type I	16,000 therms/yr or 200 th/m2/yr
Type II	10,000 therms/yr or 125 th/m2/yr
Type III	7,500 therms/yr or 95 Kwh/m2/yr
Type IV	4,500 therms/yr or 55 Kwh/m2/yr

As for Type II electric heating, these findings match those of surveys performed in 1974-1975 in major recent housing complexes after readjustment to allow for the relative mildness of that particular winter. All findings concern the Paris region.

3. Investment costs

Type I: 70 Francs/m2 for heating installation (6000 francs per dwelling unit); this cost includes the interior installation in the unit (50 francs) and the distribution system in the cluster or high-rise building (20 francs).

Type II - 95 F/m2 65 francs of it for the heating installation (1) and 30 francs per m2 for insulation in addition to Type I to comply with the new regulation.

Type III -95F/m2 35 francs of it for the heating installation and 60 francs/m2 for reinforced insulation (mainly for windows) (2)

(1) Cheaper than for Type 1 because good insulation cuts down the dimensions of heat sources but also gives more flexibility in the placement of radiators in the rooms (the reasons: less chilling of air circulating along cold walls, more even temperature in the room, particularly of its walls), and hence some savings on plumbing.

(2) EDF's argument concerning integrated electric heating is based particularly on the fact that the savings on the heating installation proper makes it possible to "pay for" the insulation absolutely necessary to bring electricity consumption down to acceptable levels.

Type IV - 160 F/m2, of which 60 francs/m2 are for reinforced insulation. This cost may seem high; in fact it was increased to allow for the fact that the mechanical equipment of the installation must be amortized in 10 years and that from the prospect of discounting over 20 years, you must therefore add to the initial cost the discounted value of replacing such equipment at around the 10th year (say 50 percent of the initial cost). However, we are dealing here with technologies that are evolving very swiftly, particularly in the area of mass production of heat pumps: the costs are also changing very fast.

All these costs are minima, corresponding to the most economical designs. The literature frequently gives higher indices. (3)

(3) For example 160/m2 for fuel-oil heat. 85/m2 for electric heat. 180/m2 for heating with heat pumps for detached dwellings with additional insulation. (Source: CVC REVUE, November-December 1975.)

B. Total discounted cost of electric heat for dwellings

On the basis of a 10-percent discount rate and an amortization corresponding to an annual payment of about 11.8 percent, the total discounted cost is obtained by adding to the investment cost the consumption over a period of 8.5 years (8.5 $\simeq$100/11.8).

For this calculation, we shall use an average price per Kwh including the fixed rate, according to the EDF rate. This average price could be 15.2 centimes. For the Type III dwelling, it works out to expenditures of 1140 francs/yr or 14.30 F/m2. This finding coincides quite well with the surveys done in the Paris region for the 1974/1975 season, which gave 12.60 francs/m2 for that winter.

We shall therefore take 15 francs per square meter per year, and the cost discounted over 20 years for Type III is then:

95 francs + 127.50 = 222.50 francs/m2

similarly, for
Type IV we have: 160 francs + 72.00 = 232.00 francs/m2

The criticism one might adduce of this evaluation has to do essentially with the realism of the EDF rate structure: we might ask whether, following periods of inflation, it may not have suffered too-marked distortion. However, one must be very prudent in any attempt to evaluate rates in connection with electric heating, and one must not forget the folloring factors:

a. Until such time as nuclear production is such that nuclear electricity plus hydraulic electricity combined can meet the minimum national winter requirements, using electricity to heat new dwellings must be considered as using fuel oil. According to EDF predictions, that tims should come around 1980.

b. As a consequence, there will be a gradual shift to nuclear power, but it will be only partial, because in winter there will always be the power provided by the "peak backup" plants, which are fired with oil or coal. According to EDF, the percentage of heating which might be considered as of nuclear origin will level off around 1985 at two thirds of residential heating consumption.

c. There will always be a considerable portion of electric heat provided by storage during slack hours, for which there is no investment in production or real high-voltage transport and which simply uses, turn by turn, equipment which is also used for other purposes. (1)

(1) Any direct attempt to find the real cost of a kilowatt hour of electricity must allow for these points, and particularly, must not be made solely on the basis of nuclear power. It must be admitted that such an effort bristles with difficulties.

C. Total discounted cost of heating with heat from mixed plants. Determining transport margins.

1. Cost of heat produced in mixed plants

For heat from electric power plants to be utilized, the temperature must reach a level sufficient for it to find applications, which rules out utilization of "exhaust" except perhaps those from gas turbines. Given this, it is the result of a technical and industrial process, and is a genuine product. The term "recovery heat" so widely used by pseudo-scientific types with superficial or poorly assimilated knowledge, must be remorselessly stamped out, because it is misleading.

We shall not be concerned here with "rigid" solutions for raising the temperature of the condenser. These solutions, which are technically attractive to producers of heat for whom electricity is a by-product obtained under advantageous conditions (with a yield of practically 1 since you get practically 1 Kwh of electricity in exchange for a thermal Kwh) are not applicable to large plants, because they lead inevitably to gigantic yields of heat which correspond to no existing requirements. We shall assume therefore that we have adopted flexible solutions of the "steam drawdown" type, which retains the option of shifting from one product to the other by substitution in the course of operations. (2)

(2) However, counter-pressure plants are interesting because they make electricity as a cheap by-product of their heat, but their power rating must be adapted to the heating system they supply. The counter-pressure principle could, however, prove somewhat advantageous even for large plants if some economically sound technique for seasonal heat storage were developed, because storage would perhaps make it feasible to obviate the major drawback of that technique, which is its rigid link between instantaneous thermal and electrical power levels, which is one of its essential features.

So there is a "substitution" equivalence between heat and electricity production. By using staged drawdown processes which would improve the substitution factor we could obtain, according to some Swedish studies:

6 thermal Kw per electric Kw lost at 165°C

9 thermal Kw per electric Kw lost at 95°C (Note)

(Note) This calls for advanced installations with downdraws at several stages. In simple solutions you get only 4 (at 165°C) to 6.5 Kw (at 95°C) Kwth per Kwe lost.

This calls for complementary installations which must be amortized and whose cost is not very well known at all. However, one apparently very competent study by the SULZER REVUE TECHNIQUE gives a yearly amortization figure of 0.82 Swiss centimes per therm (or 1.46 French centimes at present exchange rates) at around 130°C for annual operation of 5000 hours (which corresponds to a complementary supply of 50 to 70 percent of the maximum heat requirement, with the rest being supplied by local fossile-fired plants). Amortization of the local backup heat source is included in this price and, by subtraction, we can assess amortization of required modifications at about 1 centime/hr.

Apparently the price varies little with temperature, probably most at 95°C and least at around 165°C. We shall take 1 centime for both cases, so as not to risk discriminating against the low calories. However, if the additional needs are supplied by oil-fired heat plants which will thereby be used inefficiently and will not pay for themselves out of their own production, we shall have to stick with 1.46 centimes per therm.

Furthermore, because of and through the general interconnection, the real sibstitution will be done (as in the case of electric heating):

with fuel-generated electric Kwh until 1980

with a variable proportion of fuel and nuclear Kwhe from then on,

with this proportion tending to level off at 1/3 fuel, 2/3 nuclear after 1985.

The average kilowatt hour of electricity after 1985 can therefore be predicted as being:

$$1/3 \ 10.5 + 2/3 \times 6.58 = 7.88 \text{ centimes}$$

on current bases.

The value of electrical energy lost per thermal Kwh delivered then works out (on the basis of the Swedish studies) to:

at 95°	1.08 ¢/Kwh or 1.25¢/therm before 1980	
	0.88 ¢/Kwh or 1.02¢/therm after 1985	
at 165°	1.76¢/Kwh or 2.05¢/therm before 1980	
	1.31¢/Kwh or 1.53¢/therm after 1985.	

If we add the investment amortization costs for 5,000 equivalent annual hours of production, we get:

at 95°	2.25¢/th before 1980	(2.73 ¢/Kwh)
	2.02¢/th after 1985	(2.40 ¢/therm)
at 165°	3.05¢/th before 1980	(3.51 ¢/Kwh)
	2.53¢/th after 1985	(2.99 ¢/Kwh)

The costs in parentheses allow for amortization of the fuel-fired back-up heating plants. These costs are to be compared with those of the fuel-fired heating plants, currently at 5.80¢ per therm, or thereabouts.

Since distribution is the same in both cases, the transport margin is the difference between 5.80 centimes and the calculated cost, or, taking the most favorable hypothesis of mixed production (price after 1985) but retaining the back-up fuel-fired heating plants:

5.80¢ - 2.99¢ = 2.81¢ per therm at 165°

5.80¢ - 2.48¢ = 3.32¢ per therm at 95°

2. Distribution costs

To establish a comparison with electric heat, you must allow in addition for the cost of distribution by an urban system. This is a widely variable cost. We can nevertheless estimate it on the basis of urban heating rates. The total transport margin is, a priori, no more than 3.5 centimes, otherwise urban heating would not have managed to remain competitive with individual heating. In fact, if we take 20 francs per square meter of housing as the investment for the distribution system, or an annual cost of 2.36 francs per square meter for a Type I dwelling (consumption 200 therms per square meter), the amortization of the distribution system comes to 1.18 centimes per therm, and the total distribution cost to 1.50 centimes per therem (with the cost of pumping which represents around 30 percent more) at 165°. These costs can be considered as valid for average urban densities of 50 to 80 housing units or equivalent housing per hectare.

At 95°, the cost we have selected is a little higher: plumbing, if you stay with the same technology, is twice as costly, as is pumping, but you get some of this back with exchangers. You can count 26 francs per square meter or 2 centimes per therm (for Type 1 dwellings).

This gives us costs per therm, including distribution (after 1985), of:

$$\left.\begin{array}{l}\text{4.52 centimes at } 95^{o}C \\ \text{4.53 centimes at } 165^{o}C\end{array}\right\} \text{rounded off at } 4.5¢$$

<u>The gain in production due to the lowered temperature is entirely absorbed by distribution; there is no relative margin left for transport at 95°C</u>. Hence the transport price at 95°C is economically acceptable only for direct distribution without intermediate transport, absent technical advances lowering distribution costs at 95°C which would not be applicable at 165°C.

With Type II housing, distribution costs are increased because the systems are almost as costly for distributing less heat. We can assume costs of 17 francs per square meter (at 165°) and 25 francs per square meter (at 95° for consumption levels of 125 therms/m2, or distribution costs of 1.67¢ at 165° and 2.25¢ at 95°C. In all (after 1985):

$$\left.\begin{array}{l}\text{4.73 centimes at } 95^{o}C \\ \text{4.66 centimes at } 165^{o}C\end{array}\right\} \text{rounded off at } 4.7¢$$

Production at 95°C is clearly more costly, although the difference is not really significant.

3. <u>Discounted cost of heating a dwelling</u>

The discounted cost is just as good at 95°C as at 165oC (not including transport);

$$\left.\begin{array}{l}\text{for Type I housing} - 70 + 8.5 \times 200 \times 0.045 = 146.5 \text{ francs} \\ \text{for Type II housing} - 95+8.5 \times 125 \times 0.047 = 145 \text{ francs}\end{array}\right\} \begin{array}{l}\text{MEAN} \\ \text{145Fr}\end{array}$$

<u>The transport margin</u> is 77 francs for an electric dwelling Type III (87 francs for Type IV, according to reports, or:

in case 1 (Type 1) 4.5¢ per therm (at 95° or at 165°)

in case 2 (Type 2) 7.5¢ per therm (at 95° or at 165°)

(but in the second case you must not forget that the flows are 40 percent smaller, and that this has a marked impact on unit costs of transport).

In the immediate future, it is the competitive rating vis-à-vis oil heat that determines the margin available for transport.

If fuel costs increase in the future it may well be its competitive rating vis-à-vis electric heating.

These conslusions would be greatly modified if in the future we were to have available a seasonal heat storage system which would make it possible to provide winter distribution of calories made in summer; such manufacturing would not replace existing electric power production, but it would palliate the inadequacy of electric power demand by rasing the base level, which would at the same time lower the cost to the consumer of the Kwh of electricity. We may hope for a gain of as much as a centime per therm, upon which we should do well to charge the costs of storage (amortization, operation, and losses).

D. Residential electric heating and oil heating

It looked like a good idea to stop on the way and make a comparison between two types of individual residential heating.

For individual home heating with oil, the cost of the individual boiler more than makes up for the cost of piping outside the house and of distribution. You have to reckon 90 francs per square meter in Type I and 120 francs per square meter in Type II, which, coupled with fuel costs of 9.5 centimes per therm, corresponds to the real output of individual domestic boilers (with a lot of optimism), gives the following discounted bills over 20 years:

Type I	252 francs per square meter
Type II	220 francs per square meter

as compared with 222.50 francs per square meter for electric heating of a Type III dwelling.

There is good relative competitiveness for electric heat, which might in the long run win out over all other systems for scattered housing, if the relative cost of heating fuels continues to rise. We might point out, in passing, the advantages of insulation, given the price of household heating fuels.

E. Transport distances. Spatial limits of competitiveness

On the basis of 4,000 equivalent hours of transport (by which we mean an hourly flow but such that the total annual flow is equal to the total flow during 4,000 hours at this constant flow at normal power), which is enough to supply around 40 percent of the maximum requirements of a town on the coldest day of winter, with the rest coming from elsewhere -- fuel-fired plants -- but in the last analysis supplying it with at least 80 percent of its annual consumption), the transport costs per therm in centimes per 100 kilometers are shown in the following table as a function of the feeder capacity for the following two cases:

a. round-trip temperature differences of 100°C, which correspond to delivery at 165°C and return at a mean temperature of 65°C;

b. round-trip temperature difference of 30°C (or 95°/65°C);

TABLE I (2)

Nominal transport capacity in Kth/hr	ΔT 100° (165°C)	ΔT 30° (95°C)
100 Kth/hr	8.2¢ per 100 km	17.6¢ per 100 km
200 "	6.6 " " "	13.7¢ " "
500 "	4.3 " " "	9.3(3) " "
1000 "	3.5 " " "	7.5(4) " "
1500 "	2.8(3)" " "	6.5(4) " "

These costs do not allow for loss costs, nor for the cost of transport of losses. (Ms 1) (Ms 2) [illegible: see p 10 of text]

(2) These results were obtained by a method of optimization calculation not described here, on the basis of pipeline and plumbing costs from a heating company. They coincide correctly with findings from other sources, including some Swiss ones (published in the SULZER REVUE TECHNIQUE) and some Swedish ones.

(3) Values extrapolated in an area where costs are not known with any certainty (pipeline diameters greater than 1 meter).

(4) -d°- -d°- , but the pipelines are more than 1.5 meters in diameter. It seems that looking toward gradual realization, one would be well advised to double or triple them with costs which would apparently be higher, in the long run, than those shown.

The prices in the two columns correspond to use of the 10-rated steel tube as a main. Use of a different technique for low heats could bring costs closer together. However, prices of pipeline and ducts would have to be divided by 2.2 for equal diameter to reach equality, which presupposes considerable progress still not on the immediate horizon, although quite possible.

We shall adopt margins of 2.81¢ at 165°C and 3.32¢ at 95°C for fuel, and of 4.5¢ to 7.5¢ for electricity, both for hot water at 95°C and for water superheated to 165°C. The 4.5¢ value corresponds to a housing cluster made up exclusively of houses with standard insulation (Type I), and the 7.5 value to a cluster made up of dwellings with the new insulation standards (Type II).

In fact, you will generally have a mix of dwellings with various types of insulation. This may pose a rate problem. Too high a rate might encourage Type-I homeowners to insulate them better, because that would become quite profitable at such a juncture and the result would be a drop in demand which would raise costs. So new customers would have to be found, mainly in the less densely built suburban areas where higher distribution costs would increase the transport margin. It would therefore be rash to believe that you would really have a 7.5¢ transport margin and to calculate your maximum distances on that basis.

The calculation was nevertheless run, <u>for purposes of enlightenment only</u>, to assess the effect which a cutback in flows might have, for a given population, if the dwellings were insulated.

1. <u>Spatial limits of competitiveness in relation to heat production by a local urban heating plant burning fossil fuels (F.O.2.).</u>

TABLE II

Feeder power	Population of the subdivision or town supplied		Maximum transport distances	
	Case A. Type I dwellings, 40% supply	Case B. Type II dwellings, 40% supply	Hot water	Superhot water
	Demand 1th/hr per cap. (1)	Demand 0.65th per hr/capita	95°C	165°C
100 Kth/hr	100,000	165,000	18km(15km)	27 km
200 Kth/hr	200,000	330,000	22km(19km)	34 km
500 Kth/hr	500,000	825,000	33km(27km)	53 km
1000 Kth/hr	1,000,000	1,650,000	44km[2](35km)	68 km
1500 Kth/hr	1,500,000	2,500,000	48km[2](41km)	86 km

(1) 1 therm per hour per capita x 4000 hours per year x 3.3 inhabitants , log^t = 13,200 th/yr + fuel backup 15% = 16,000 th/yr x log^t.

(2) Very dubious values.

This table allows for <u>losses</u> and their transport cost, which explains why the maximum distances shown are slightly shorter than those which would result from a simple division of the margin by the indications in Table I. These reductions are just about constant whatever the population (because the relative losses grow as distance but drop as transport power, and wind up roughly even).

Insodar as water at 95°C is concerned, the first mumber results from a comparison with an urban heating syatem with 95° distribution, the number in parenthesis results from a comparison with an urban heating system with direct distribution at 165°C slightly less costly, which, of course, cannot be tied into 95° transport systems. The margin is thereby narrowed by 0.5 centimes per therm.

We have kept the kilometer number turned up by the calculation. It is of course understood that on the level of precision of this study, it has no significance at all. The only advantage in retaining it was to give an idea of the order of magnitude of certain factors.

Insofar as population is concerned, we have assumed that the entire population was on the system, which is obviously quite an optimistic assumption. On the other hand, we did not allow for the profitable contribution of tertiary activities, which is quantitatively equivalent to an increase in population, and qualitative as well, because tertiary demand is most often spread out over time and thus has a levelling effect on the graph of demand variation.

Potable hot water, the demand fo which is better distributed, is also an improvement factor.

The values given for 1000 and 1500 kilotherms per hour at 95°C are very dubious. It is quite likely that you would be well advised to use doubled or tripled piping and to limit the distance to around 30 kilometers for reasons having to do with gradual realization. A technical drop of 50 percent in the cost of pipes usable at 95°C would bring that maximum up to around 50 km.

2. <u>Spatial limit of competitiveness between hot water (95°C) and superheated water (165°C from power plants.</u>

Hot water gas a relative margin of 0.51¢ per therm.

This is <u>entirely absorbed</u> by distribution when you compare distribution at 95°C with distribution at 165°C. The competitive limit for hot water thus becomes zero.

This margin persists if you are contemplating providing 95°C distribution in both cases, something which may occur. The 0.51¢ margin then is completely consumed after 6 kilometers (for 100 Kth per hour) or 14 kilometers (for 1000 Kth per hour), distances which are as a rule shorter than those between a town and a very large plant -- particularly a nuclear plant -- <u>except in rare cases in the present state of affairs hot water is never competitive with superheated water, unless there is local production and direct distribution. It will take considerable progress in transport technology</u> for water at 95°C (though not at 165°C) <u>to make even a minor change in this situation</u>.

3. **Spatial limits to competitiveness between hot or superheated water and electric heating**

TABLE III

Feeder power	Type I housing (margin 4.5¢/th) Town population	Maximum distances (km) 95°C	Maximum distances (km) 165°C	Type II housing (margin 7.5¢/th) Town population	Maximum distances (km) 95°C	Maximum distances (km) 165°C
100 Kth/hr	100,000	26	42	165,000	37	70
200 Kth/hr	200,000	33	55	330,000	49	89
500 Kth/hr	500,000	50	81	825,000	74	132
1,000 Kth/hr	1,000,000	(62)[1]	104	1,650,000	89[1]	172
1,500 Kth/hr	1,500,000	(72)[1]	132	2,500,000	(100)[1]	200

(1) Very dubious values (see text).

Distribution is at the same temperature as transport.

The hypotheses for population are those already assumed for Case I, Table II.

For reasons explained earlier the columns concerning Type II housing are of only very slight interest insofar an formulation of an installation policy is concerned. It is prodent to maintain a corresponding distance with respect to Type I housing.

The values indicated for 1,000 and 1,500 Kth/hr at 95°C should be viewed as highly dubious. It would seem that it would be logical to double or triple the piping and to limit distances to 50 kilometers.

Consideration of phased construction may lead to analogous considerations concerning heavy flows of 1,000 to 1,500 Kth/hr; even at 165°C, the limiting distances would then be around 80 to 100 kilometers. You will note that 1,500 Kth per hour would mean pipelines 1300mm in diameter at 165°C.

Construction all at once of 1000- to 1500-Kth/hr feeders is conceivable to connect a feeder with a community already equipped completely with distribution facilities, but not if you are talking about a community just in the process of providing itself with such equipment, because that would lead to too-early completion of a system which would be fully utilized only 10 or 15 years later. This would give rise to costly interim interest costs, not to mention excessive heat losses.

All the calculations concerning the cases in Tables II and III were arrived at by assuming that the feeder was supplying a single client. They let you get an idea of the outside limits of distance for supplying a major but isolated community. When you have several communities close to one another, they can perhaps be supplied by a single feeder or by several feeders with a common trunk line, which is obviously a factor in its favor. There still has to be a study made for each individual case. By the same token, a small town on the line toward a bog one (1) can take advantage of the big one's feeder, just as a medium-size town just beyond a big one can be supplied by means of a common main, even if it lies outside the zone where it might expect such service were it totally isolated.

The fact remains, though, that distances of 35 to 50 kilometers for hot water and of 80 to 100 kilometers for superheated water seem perforce to constitute absolute practical maxima even in exceptionally favorable cases. We are a long way from some people's midnight pipe-dreams.....

F. The roles heat-storage can play

Seasonal storage will indeed, if we manage to develop it at reasonable rates, let us even out heat production by spreading it over the year (and hence maybe let us use the technique of upping the condenser temperature, also known as the counter-pressure technique), or again, in summer, to use some drawdown technique instead of going on with electricity production not needed at that time, to produce calories to be used in winter, at which point we can legitimately discount them at marginal cost which may even be lower than the cost as shown by a margin computation (since these calories would be replacing a product for which there is no market); better utilization of plants is assured, and might even be translated into a drop in the cost of a kilowatt hour.

If storage is handled on the production site, the problem of transport remains the same as in the "no storage" case: covering basic needs out of storage, peak demand handled by local heating plants. The appearance of a margin capable of covering storage costs then comes via a reduction in production costs through regularization of production. Combined production of heat and electricity is reflected in a rise in the base of power production which becomes a mixed base. The problem of the available margin for storage is to be found on the level of the overall national system of electric power production and of the direction it takes.

If storage is done on the consumption site, it becomes possible to start your distribution from the storage facility, rather than from transport, which eliminates the problem of winter peaks and backup heating plants. The cost of transport then is linked with the rate of production, no longer tied to the pace of consumption; transport is either distributed over the year (with the equivalent duration of transport then exceeding 4000 to 5000 hours), which diminishes your transport cost, or are concentrated in summertime and winter slack hours, which comes to the same thing because the electricity for pumping then is billed at slack or summer rates, corresponding to marginal power production, which makes it possible to use smaller pipe diameters (1), with the increased consumption being covered by the cut in average rates.

(1) It can be shown that at minimal transport costs, there is a constant relationship, no matter what the equivalent operating schedule, between the annual pumping cost (power consumption plus pump maintenance plus pump amortization, with the latter item very small) and on the other hand the annual cost of amortizing the transport pipeline. Pumping represents 30 percent of that annual cost. By using cheaper energy for pumping, you cut down on your annual costs. In the final analysis, the optimal pipeline diameter will depend on economic considerations rather than on technical ones, most particularly on the selling price for the electricity used for pumping.

Increasing the storage margin can then lead to a cut in the cost of transport, over equal distance. But then the problem arises at the level of storage technology. That seems to be very sensitive to the scale effect: consumption-site storage facilities may well turn out to be a lot of very small facilities, more costly than big ones in investments, operation, and losses. We need a better knowledge of the technical potentials of storage facilities before this problem can be approached on a practical basis.

Lastly, the solution embracing both storage at the plant site and at the consumption site or at least on site for the biggest consumers, is worth looking into. It looks as though large-scale common storage sites could profitably be shared by several consumers.

Extending the annual hours of transport beyond 4,000 to 5,000 hours or concentrating them in summertime (so as to take advantage of cheaper Kwh) do not cut down transport costs and do not expand the profitability radii to any considerable extent (10 percent at most). Doing away with backup and emergency plants gives a margin of 0.5 centimes per Kth; and the margin that might stem fromcuts in production costs due to the availability of storage, if it is really cheap, can put an additional edle on it. (We should not conclude from this remark that the benefits of storage are nugatory: they have to do more frequently less with a decline in the specific price per therm delivered than with the quantity of therms delivered from the plant to the consumer, to replace local production.

G. <u>Potable hot water and its role in the economics of heat transport</u>.

The statistics on real consumption, particularly those which have been gathered in electrically heated dwellings, show that an average household consumes around 2500 Kwh per year, or 30 Kwh per square meter (or 26 therms).

With electric heating, the best solution is local heating by individual storage (cost 4.4 francs per square meter per year according to the statistics). But in these statistics, electricity is charged off at a single mean rate from a common meter for all individual domestic uses, whereas in reality water is heated in slack hours without increasing the power load and it would therefore be more logical to assign it a slack-hour rate without the fixed rate, or 7 centimes per Kwh (8¢ per therm), and hence in the final analysis a cost of 2.10 francs oer square meter per year.

If potable hot water is produced along with hot-water heating, consumption is far greater.

In effect, either the potable water is prepared at the level of an average building with a small distribution system, which means that in summertime you have to keep in service to that building the primary heating system of a setup whose absolute losses are the same as in midwinter, and hence that the relative losses are sharply increased.

If, on the contrary, your potable hot water is prepared at the plant level, it requires a very extensive distribution system whose losses will perforce be very high when you relate them to a small flow for distribution of hot water. This is complicated by the fact that, to avoid making a user at slack hours run enormous amounts of cold or lukewarm water before he gets really hot water, and to cause him to empty only a reasonable quantity from the cold pipes, large hot-water distribution systems are in actuality closed loops with permanent circulation into which the <u>short</u> hookups for consumers are plugged.

You can see that, in a system like this, the losses are going to be considerable: this is why we generally take 4000 therms per year as the consumption mean for a dwelling, instead of 2100 (the equivalent of 2500 Kwh) for individual electric production.

Another factor in the problem of providing potable hot water from a collective heating installation is that superheating water calls for a minimum temperature in the outgoing heat distribution circuit (which is generally estimated at 80°C), whereas heat alone could get along in spring and fall with lower outgoing temperatures, which would make it possible to reduce system losses by quite some and no little. Providing hot water is responsible for quite a bit of those losses, because it is the thing that pushes them up by requiring that the setting of the primary circuits below 80°C be a setting for variable flow and constant temperature (at least 80°C), whereas a variable temperature at constant flow would be more advantageous. (1)

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(1) This is true only of therms relatively costly at the plant site and in the distribution systems. With free or very cheap therms, it is on the contrary to your advantage to vary the flow and hold the temperature constant so as to cut down pumping costs because you don't care a hoot about losses. For <u>long-distance transport</u> the situation is the same, and unless you are dealing with therms that are really very costly at the point of origin, the pumping cost is greater than that of losses, and it is preferable to transport with modulation of flow and outgoing temperature practically fixed, with the return temperature inevitably dependent on utilization conditions.

We have a comlex question here, and you will understand that we can talk about it only in necessarily clumsy and approximate terms. We can assume that therms consumed in winter (approximately 50 percent of the total), being marginal with relation to heating, would cost about the same as therms for "heating." But the fact is that therms consumed during the summer (the other half) have a cost equal to the cost of production because it costs almost nothing to transport them. The specific consumption of energy for pumping per therm varies just about as the square of the flow and the summer flow may be only 20 percent of the winter flow, consumption per therm in summer is only 4 percent of the specific consumption in winter; the electric energy being also much less costly in summer than in winter, the specific cost of transport in summer turns out in the end to be only 2 to 3 percent of the cost of transport in winter, and is therefore negligible.

We can therefore assume that the cost per therm in potable hot water is equal to:

$\frac{1}{2}$ the price per heating therm delivered

+ $\frac{1}{2}$ the price per therm at the production plant.

But hot water gives rise to enormous losses (generally equal to the heat really utilized): the price of the "hot water" therm <u>really</u> utilized is therefore in the final analysis equal to:

price of a heating therm delivered in winter
+ price of a therm at the plant in summer.

If we assume that the price of the delivered therm is competitive with oil heat (marginal price less than 4.8 centimes), and if the price of the therm at the plant is 2.5 to 3 centimes (at 95°C or 165°C after 1985 and before 1980), the total price will come to around 7.8 centimes in 1980, 7.3 centimes after 1985, and is very close to the cost you get with electric heat with storage, with investments, although different in kind, comparable in both cases.

What we have here is a blank operation, with the differences found insignificant in view of the approximate nature of the considerations we could entertain in this field.

The situation, however, looks very favorable for supplying potable hot water from a heating system. In fact, that supply might logically be written off in summer at marginal cost, because modifications to plants are obviously amortized by winter or between-season consumption in parallel with heat; one can logically not amortize them on summer production and hence discount it at 1.76¢ (before 1980) or 1.31centimes (after 1985), or even less insofar as it replaces electricity production for which there is no demand. We might go so far as to allow only for the cost of the nuclear fuel, and that brings us out with 0.20 or 0.30 centimes per therm. The conslusion at this point is simple: combined supply of potable hot water will always be economically profitable, but you must not count on it as increasing your competitive stance: it will always be an ancillary source of profit.

GENERAL CONSLUSIONS

These are obvious:

A. <u>On the general level</u>

a. Electric heating is already the imperative choice over domestic oil heat in the <u>single-family dwelling</u>; an increase in the price of fuel in the future can only heighten this competitive advantage.

b. In towns or subdivisions which can be supplied from mixed electric power stations, it would seem that hot water or superheated water heating has a sound competitive edge. However, superheated water given present available technology enjoys a net advantage once the transport distances exceed a few kilometers. Using "low-temperature" calories would be interesting only if very considerable progress massively lowered their transport cost. Even so, the interest would still be limited.

c. A <u>good technology for seasonal storage</u> of heat would <u>considerably</u> increase the incentive for electric power plants to produce heat. By raising the level of the electricity base, which would then be a common base, it would lead to a simultaneous drop in the prices of both heat and electricity. It would make it feasible to use certain heat production technologies which are now either out of the question or confined to limited use because of their rigidity (counter-pressure systems). Finally, the result would be a diminution in heat pollution in summer due to electric power plants, the only real one.

B. As for the spatial limits to competitiveness, they are these:

Extremely important though it may be in relation to fuel or electricity for superheated water produced by plants (40 to 160 kilometers according to the size of the client community);

Important for hot water under the same conditions (low-temperature calories at 95°C) with lower limits, however (several tens of kilometers);

On the other hand zero or very slightfor that same hot water when you compare it with superheated water which could be produced in the same plants.

For the very large transport system, it is obvious that the future belongs to superheated water rather than to hot water. It is better not to fall victim to the "low temperature" psychosis which seems to have attacked some of our contemporaries since the oil crisis. (1)

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(1) The relatively low cost of crude oil and its all but continuous decline over the past decade were hardly conducive to conservation. That led to a failure to pay adequate attention to combined processes for producing hear and electricity, and to the fuel economies to which they would give rise. The oil crisis triggered a reaction which, in some people, went beyond measure. They assigned excessive importance to the initial cost of therm production and underestimated the problems of transport and utilization. The cost of production of a therm is furthermore incorrectly estimated as a result of the over-simplified and often abusive application in the economic domain of a factor of technical equivalence between loss of electrical production and loss of head production. Lastly, they have forgotten that with the low relative cost of nuclear fuels, the rise of nuclear power would rather tend to reestablish the conditions which were at the root of the status quo ante.